Volatile release from intrusive magma systems

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The atmosphere on early Earth is crucial for the emergence and evolution of life. After intense destruction of the primary atmosphere and the crystallization of the magma ocean, magmatic outgassing is the main volatile source. It influences the formation and composition of the secondary atmosphere strongly and thus the habitability of the Earth. The outgassing process includes the well-studied extrusive as well as the often neglected intrusive volatile release. However, it is assumed that the intrusive magma production rates are significantly higher compared to extrusive rates, which makes the investigation and quantification of possible volatile exsolution processes even more important.

We simulate the crystallization of an intrusive magma body emplaced at different depths within the lithosphere. As the solubility of volatiles like H_2O and CO_2 increases with pressure, they usually do not exsolve from the melt. However, through the precipitation of nominally dry minerals, the remaining melt is enriched in incompatible elements and volatiles. They accumulate until a saturation level is reached and the volatiles exsolve. The composition of the resulting fluid phase depends on the solubility of the volatile species, the pressure and temperature, the initial composition of the melt, the partition coefficient and the oxygen fugacity. We consider these parameters in our model and benchmark our results with literature values of basalts and melt inclusions. Additionally, we investigate the likelihood of reactions with the surrounding mantle, to form water-bearing minerals, during the ascent of volatiles. Finally, we compare our results with studies on extrusive outgassing to determine the impact of intrusive degassing on the build-up and composition of the atmosphere.